Evaluating Meteorological Dust Events and Machine-Learning Based Dust Identification in Geostationary Satellite Imagery

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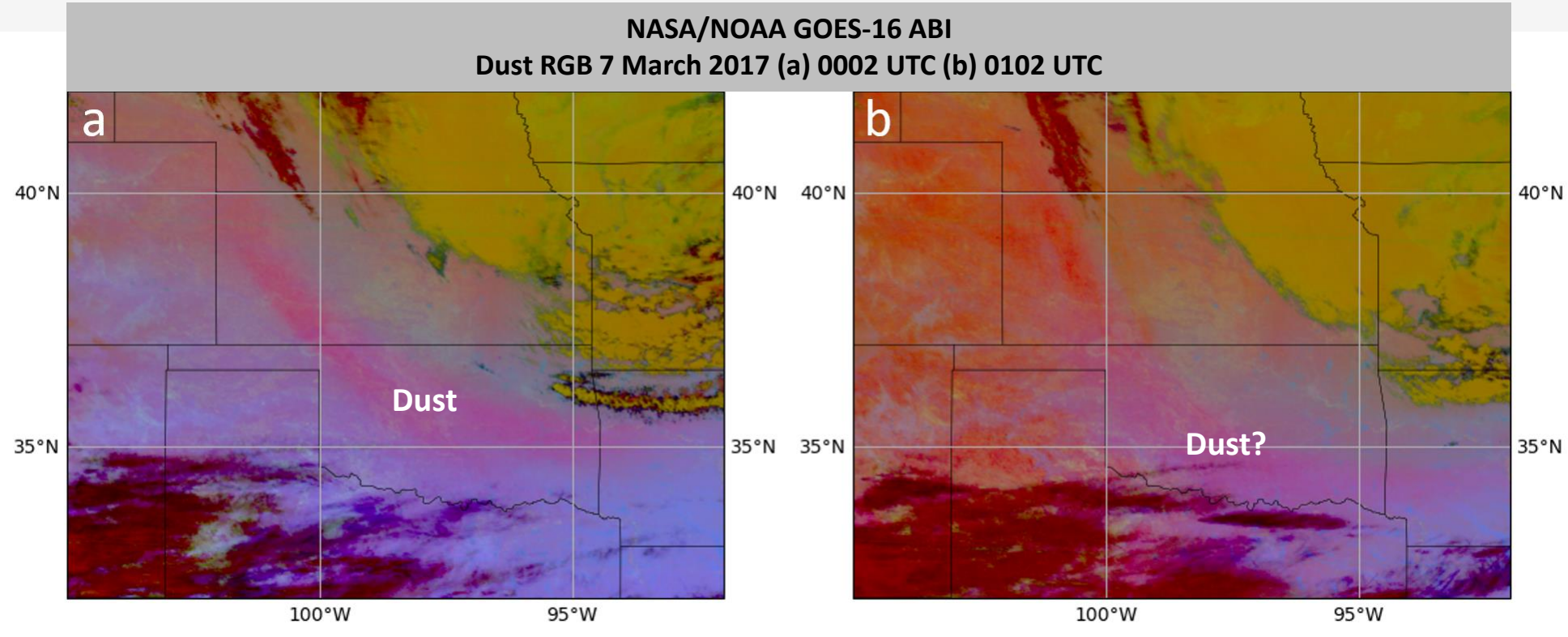
Agenda

- Brief Introduction to the GOES East DustTracker-AI Product
- Evaluating Meteorological Drivers In The Training, Testing, and Validation Datasets
- Database & Documentation
- Summary of Events
- Thunderstorm Outflow Test Cases

Introduction DustTrack-AI

- NASA SPoRT introduced the "Dust RGB" via NASA satellites to demonstrate GOES-R ABI capabilities and then evaluated the impact in operations (Fuell et al. 2016)

- The Dust RGB allows for continued dust detection at night, but the cooling ground surface limits the effectiveness as night progresses.



SPoRT has developed a 'Machine Learning' (ML) model using a physically-based approach which can correctly label 85% of dust pixels and 99% of no-dust pixels in GOES-16 imagery (Berndt et al. 2021)


Credit: NASA's Scientific Visualization Studio
07 Apr 2022 11:21

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Documentation:

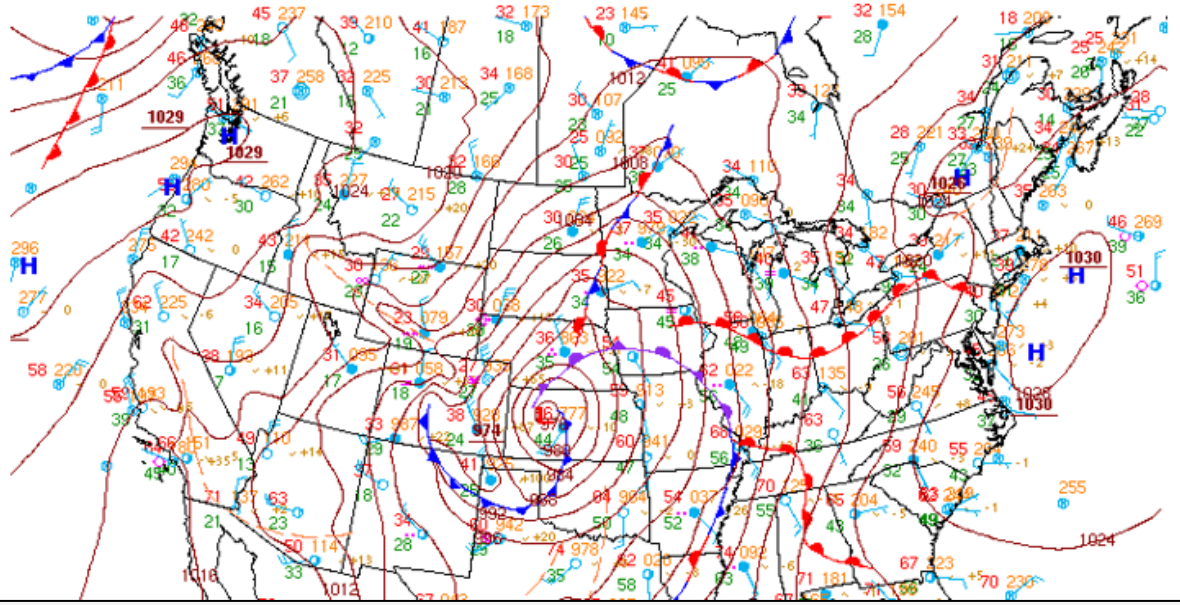
- **Goal:** Provide a more detailed synopsis of the weather related to the captured dust event.
- Initiation and ending times for the entire event outside of the training image times were included for reference.
- Initiation Lat/Lon included to aid in determining soil conditions and dust source regions.
- Images Included:
  - Surface observation map.
  - 500mb observation map.
  - Skew-T plots from observed Radiosonde data.

Date: March 14th, 2019 T 010200 - 030200 - 050200 - 070200 – 110200 | **Initiation** 03/13/2019 T 170200, **End** 03/14/2019 T 083200

Initiation Lat/Lon: 33.286, -104.589 | 32.644, -101.569 | 34.965, -102.691

Event Description:

A strong low-pressure system and associated pressure gradient centered over Kansas propagates to the northeast over the event duration. The main driver for this event was the pre-frontal winds that both initiated and sustained the dust event. In the first image wind velocities in the identified dust region were around 30kt sustained with some gusts getting close to 45kt. Winds are not as intense later in the event when the dust becomes more widespread, however, they are still around 20kt sustained. In the 050200 image the dust signals in Missouri are likely primarily lofted as METARs do not have indications of dust or blowing dust nor impacts upon surface visibility. The locations for event initiation given above are from the system initiating additional dust plumes during the full duration of the event.



Meteorological Drivers

Primary = 16

- *Synoptic* = 14
  - Post-frontal winds = 12
  - Pre-frontal winds = 1
  - Post Dry Line = 1
- *Mesoscale* = 2
  - Winds = 2

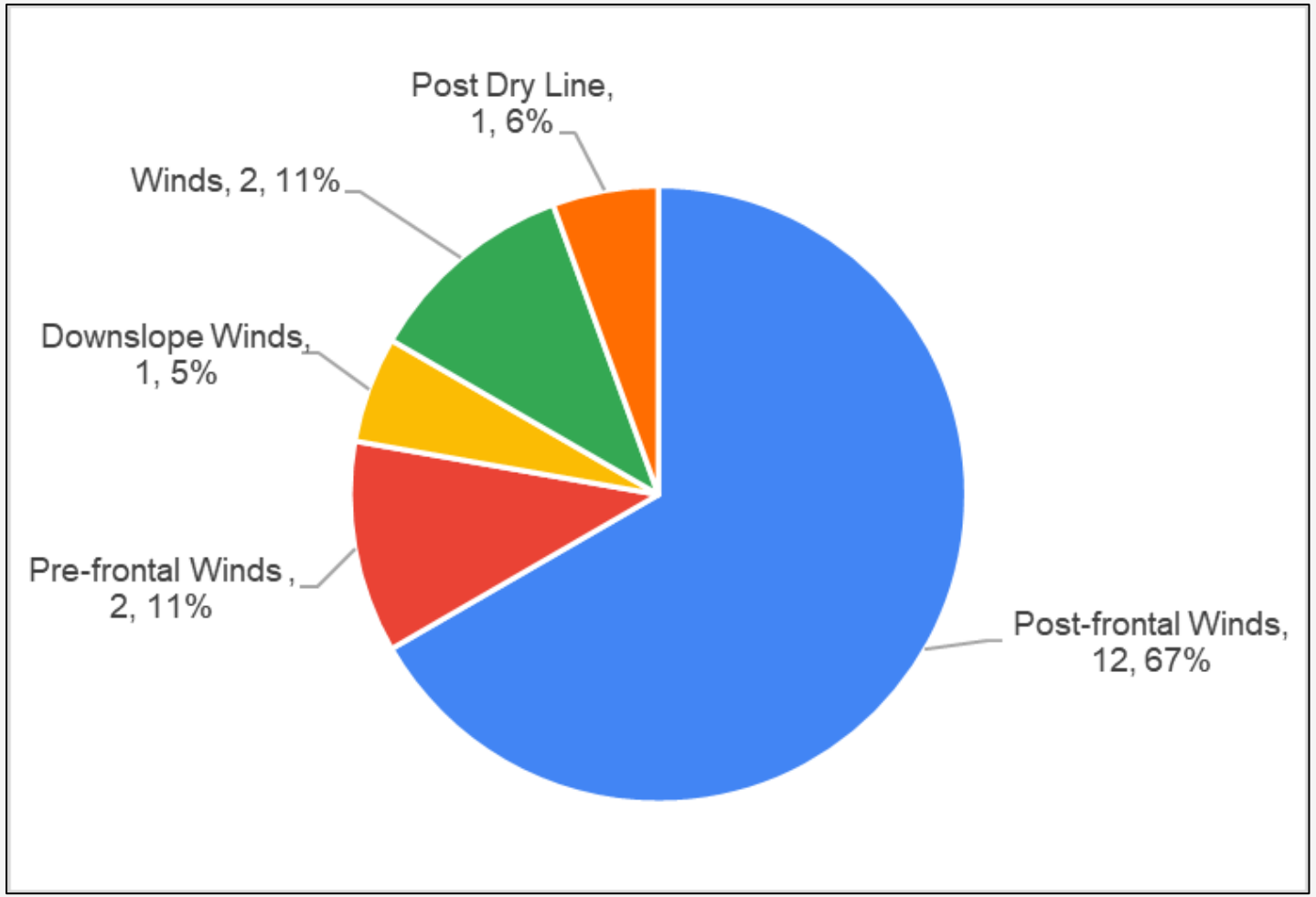
Secondary = 2

- Pre-frontal winds = 1
- Downslope winds = 1

Dust Training Only : 9 total (5 Surface, 4 Lofted)

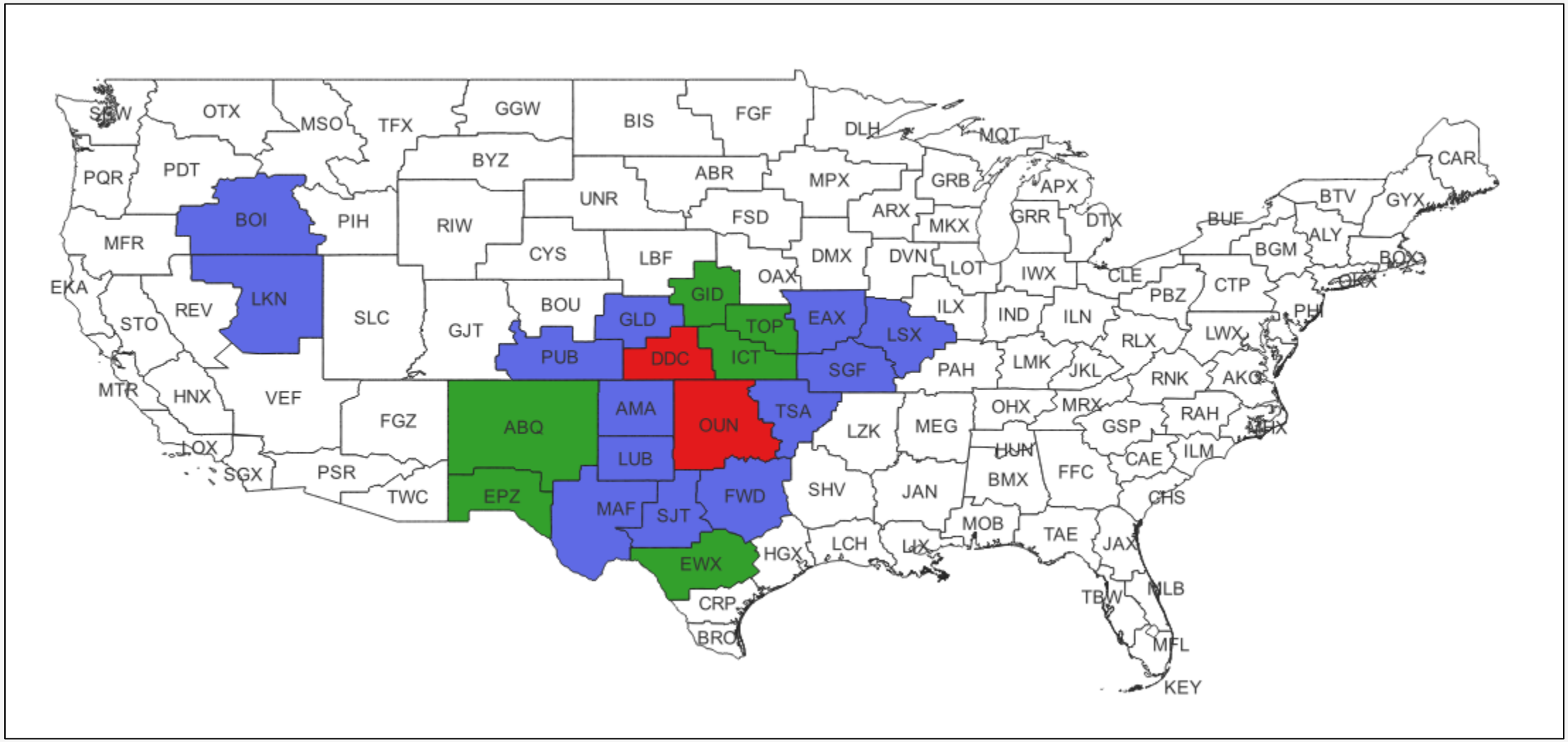
- Post-frontal = 5 -- 56%
- Pre-frontal = 1 --11%
- Post Dry Line = 1 -- 11%
- Winds = 2 -- 22%

Total of Each Met. Driver (All Dust Events)

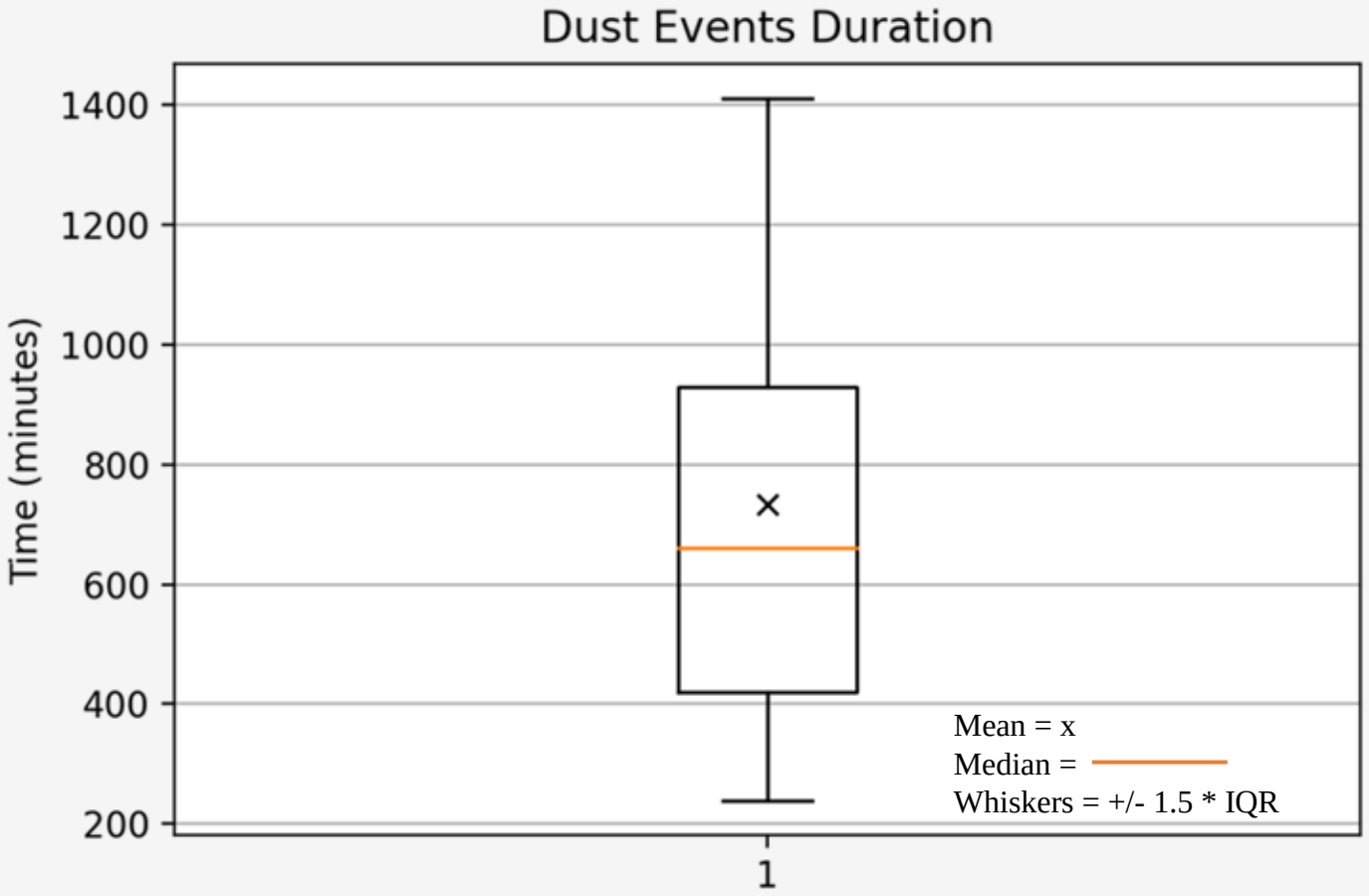


Dust Training Event Count Per Forecast Area

*Green = 1 *Blue = 2 *Red = 3

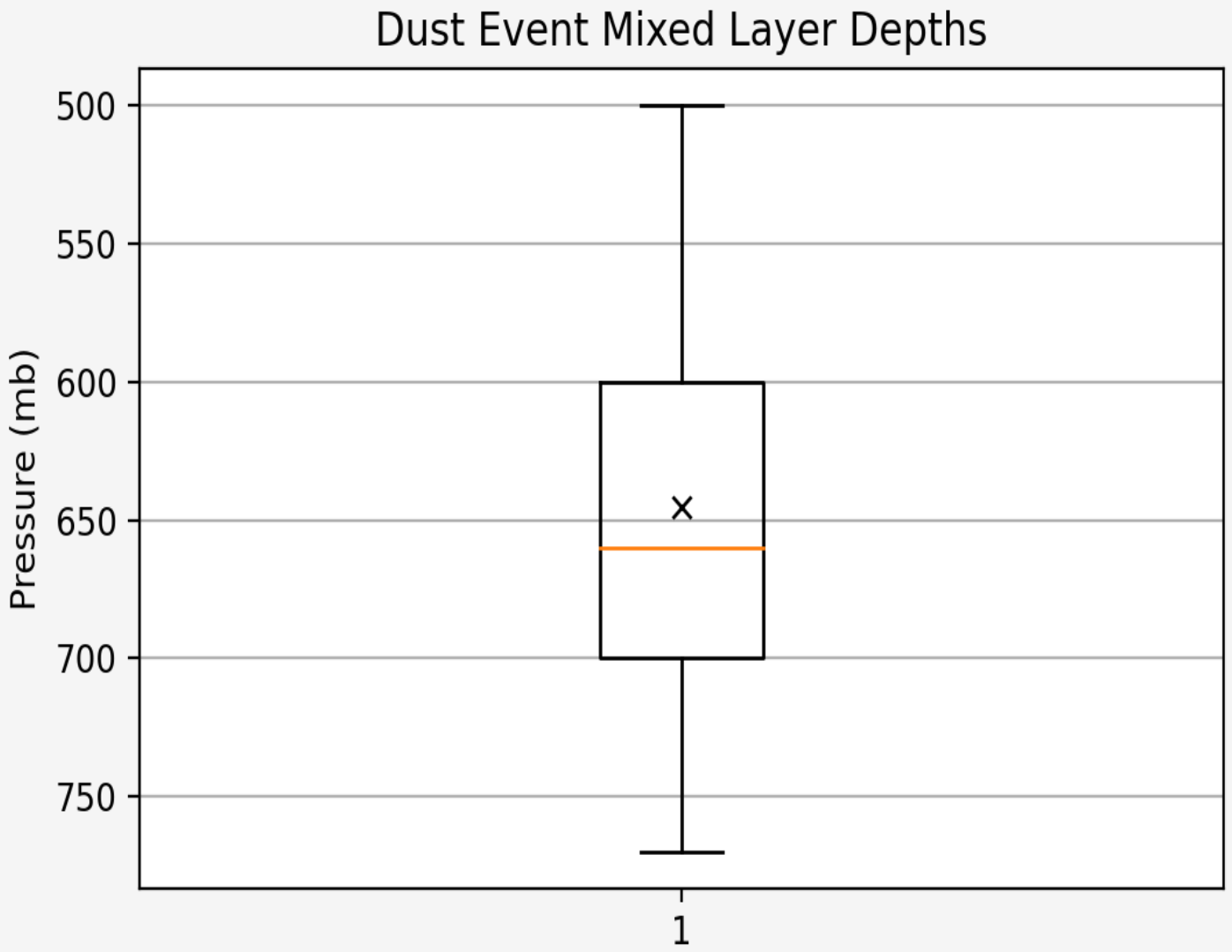


Timing and Duration of Characterized Dust Events

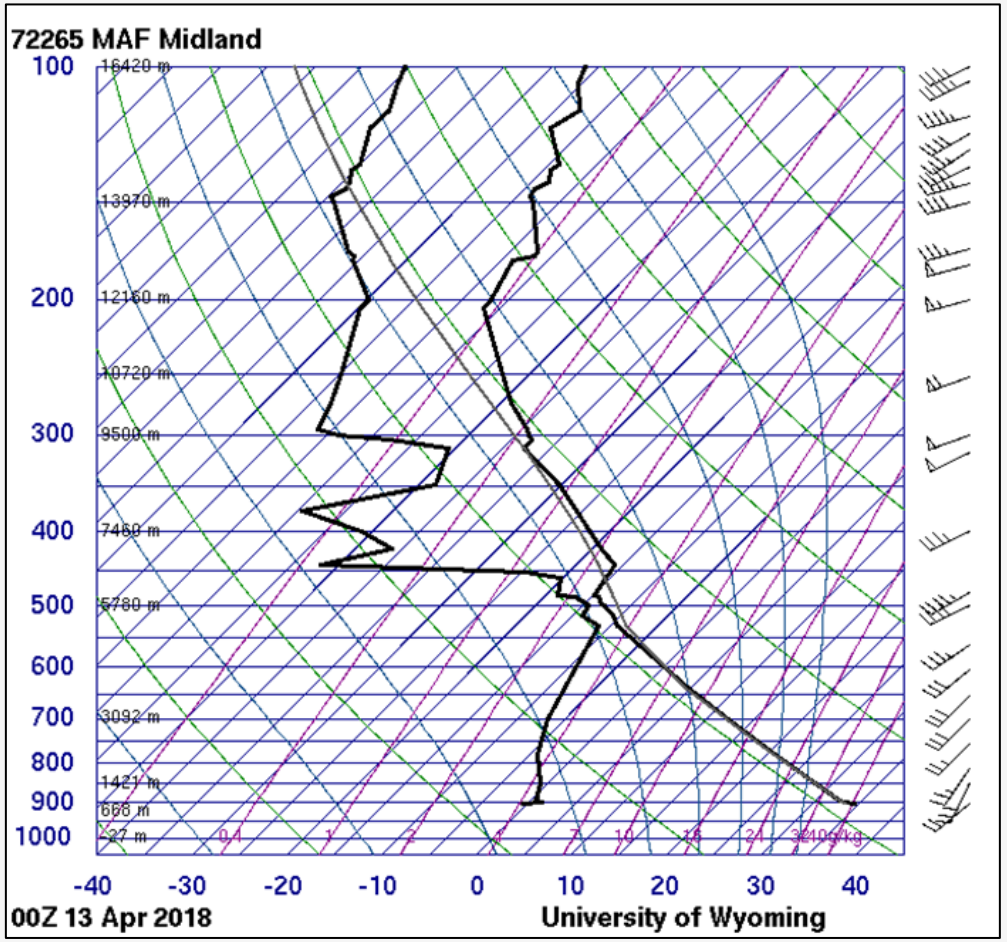


	label	lower_whisker	lower_quartile	median	upper_quartile	upper_whisker	mean
0	ALL	240.0	420.0	660.0	930.0	1410.0	733.5

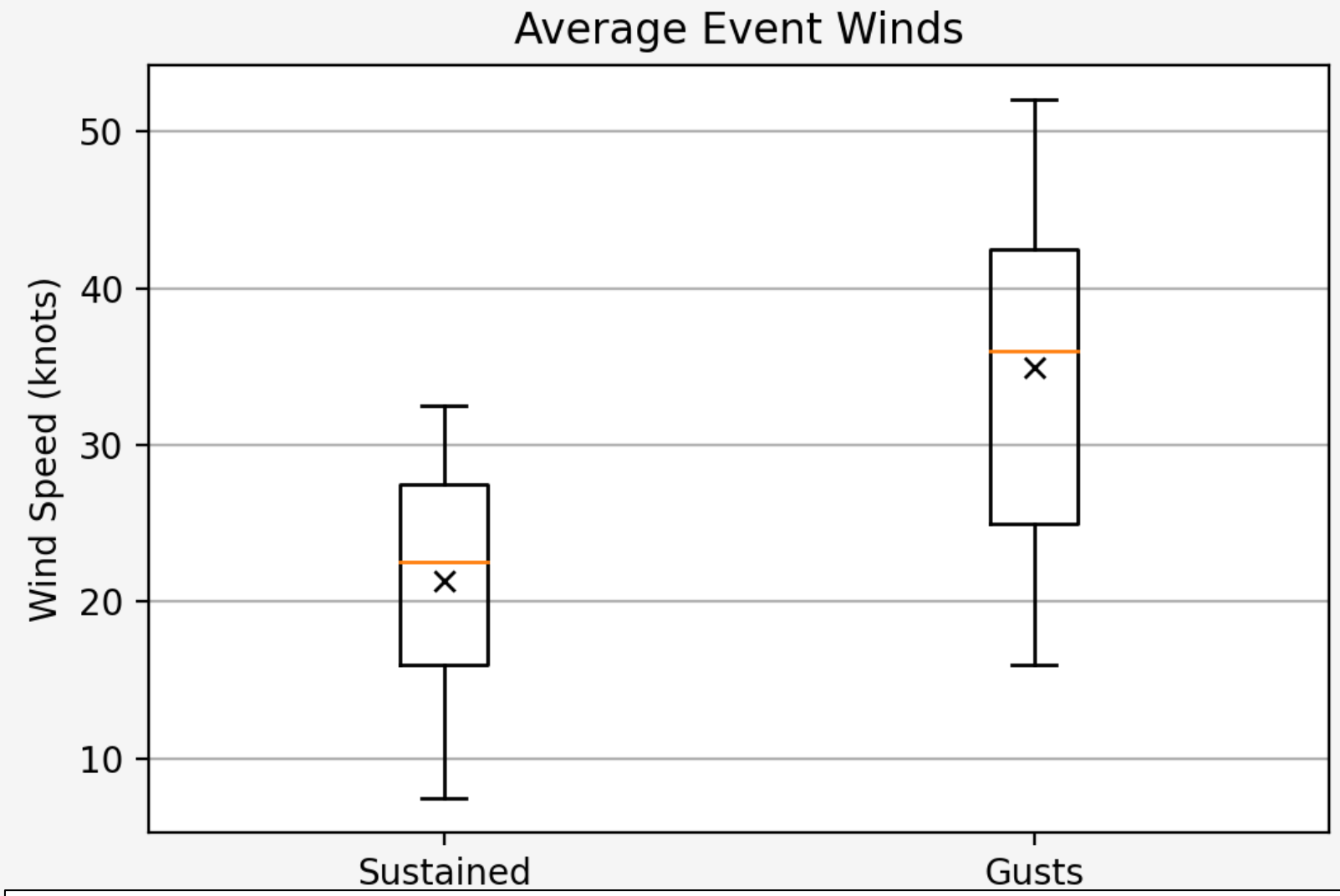
- **Seasonal Distribution**
  - Spring Event Count = 7
  - Fall Event Count = 2
- **Hourly Coverage of Events**
  - Event Images covered hours from 0-11 UTC (6pm – 5am CST)
  - Most events started at 00 UTC or 01 UTC
  - Longer duration events typically lead to images covering the 05-11UTC hours.
- **Dust Training Event Duration**
  - Full range was from 2 hours 30 minutes as the shortest to 24 hours as the longest duration.
  - Mean = 12 hours ~14 minutes
  - Median = 11 hours



Example Sounding



	label	lower_whisker	lower_quartile	median	upper_quartile	upper_whisker	mean
0	Mixing Layer Depth (mb)	500.0	600.0	660.0	700.0	770.0	645.3



	label	lower_whisker	lower_quartile	median	upper_quartile	upper_whisker	mean
0	Sustained	7.5	16.0	22.5	27.5	32.5	21.4
1	Gusts	16.0	25.0	36.0	42.5	52.0	34.9

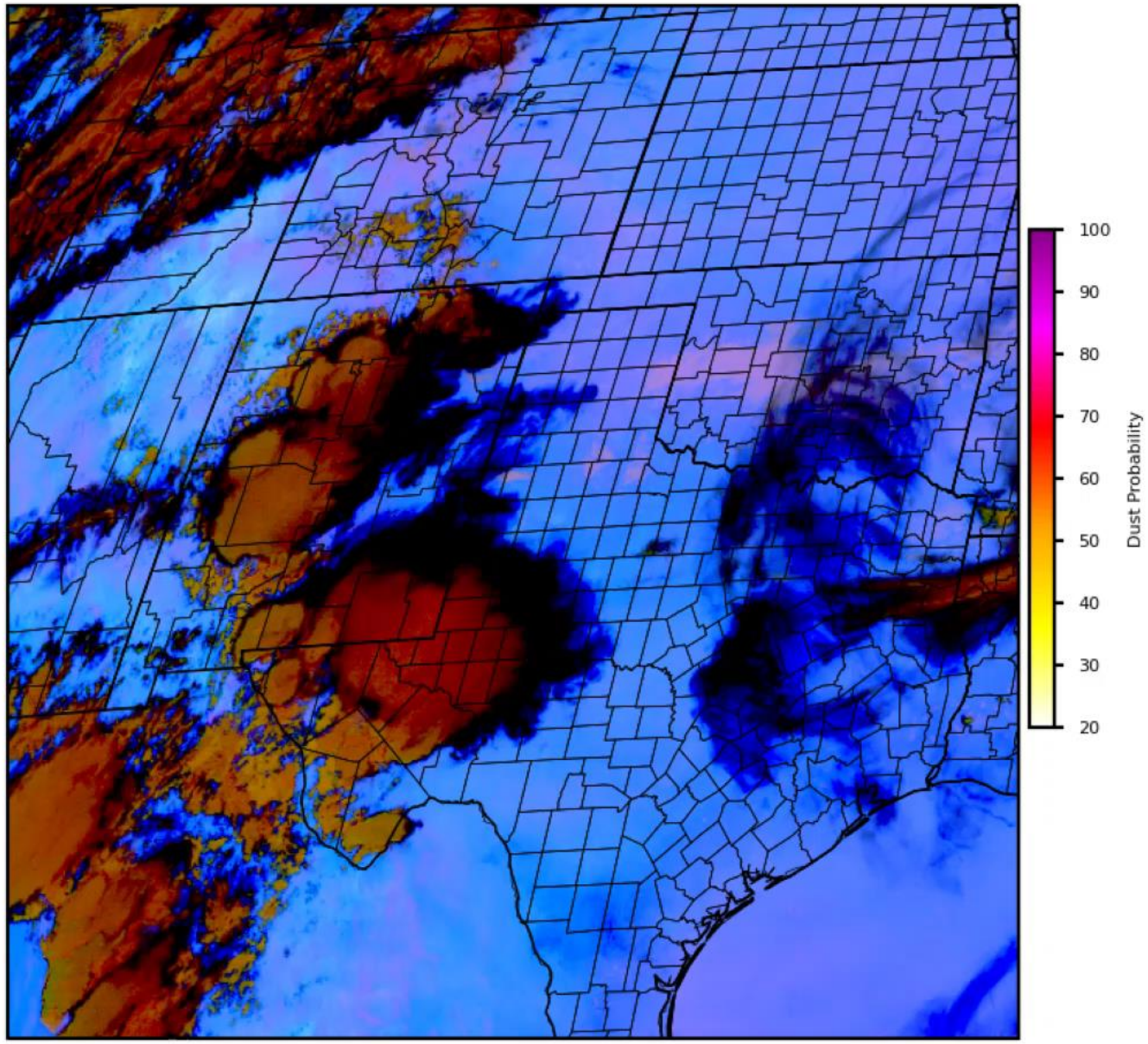
Classification Key Takeaways

- Most of the Dust training images occur during the Spring season.
- Night coverage of images seems good however, most of the events start at 00z or 01z and the duration of event is what provides the coverage into the early morning.
- Wind speeds are generally higher and correspond with some impressive mixed layers behind cold fronts and dry lines.
- The model has a heavy focus on synoptically driven events in training, testing, and validation.

What Could Be Missing?

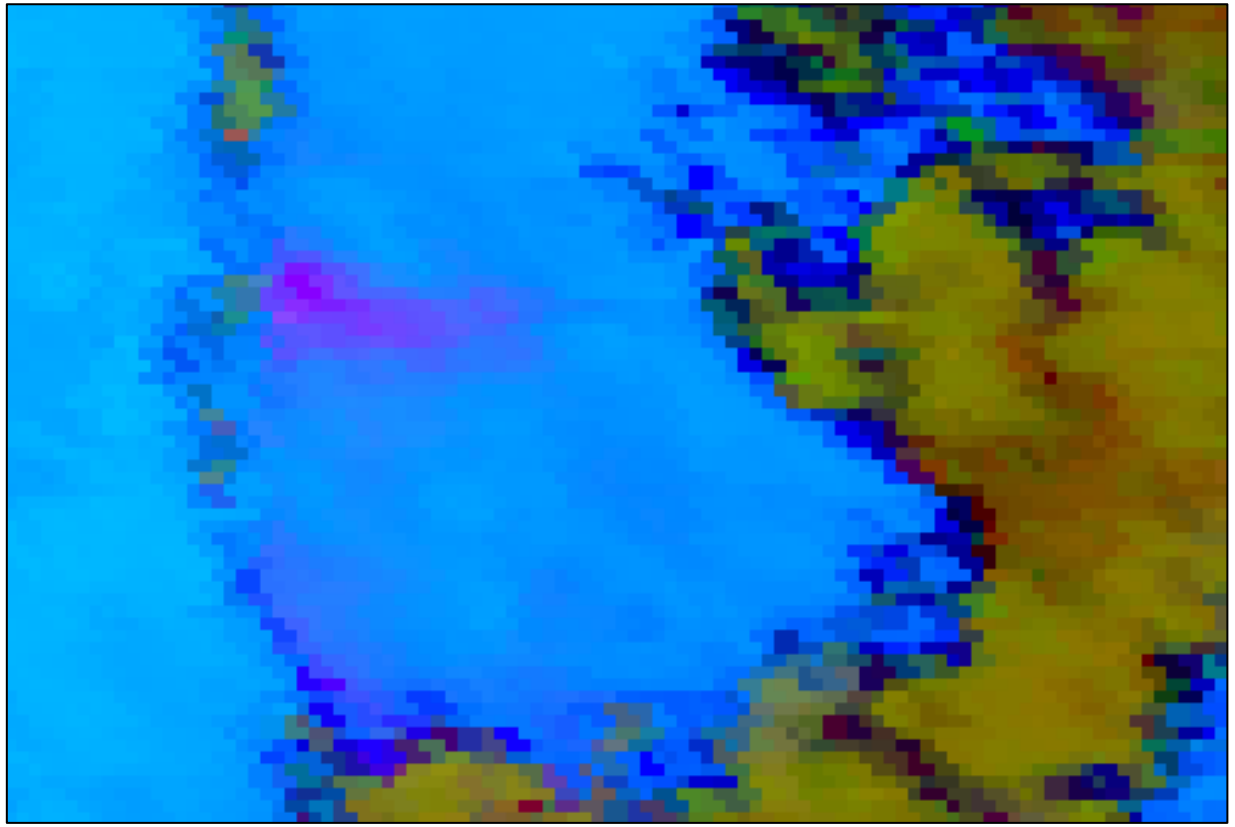
Base

GOES-16 ABI Dust RGB with Dust Probabilities 2022-06-08 23:56 UTC

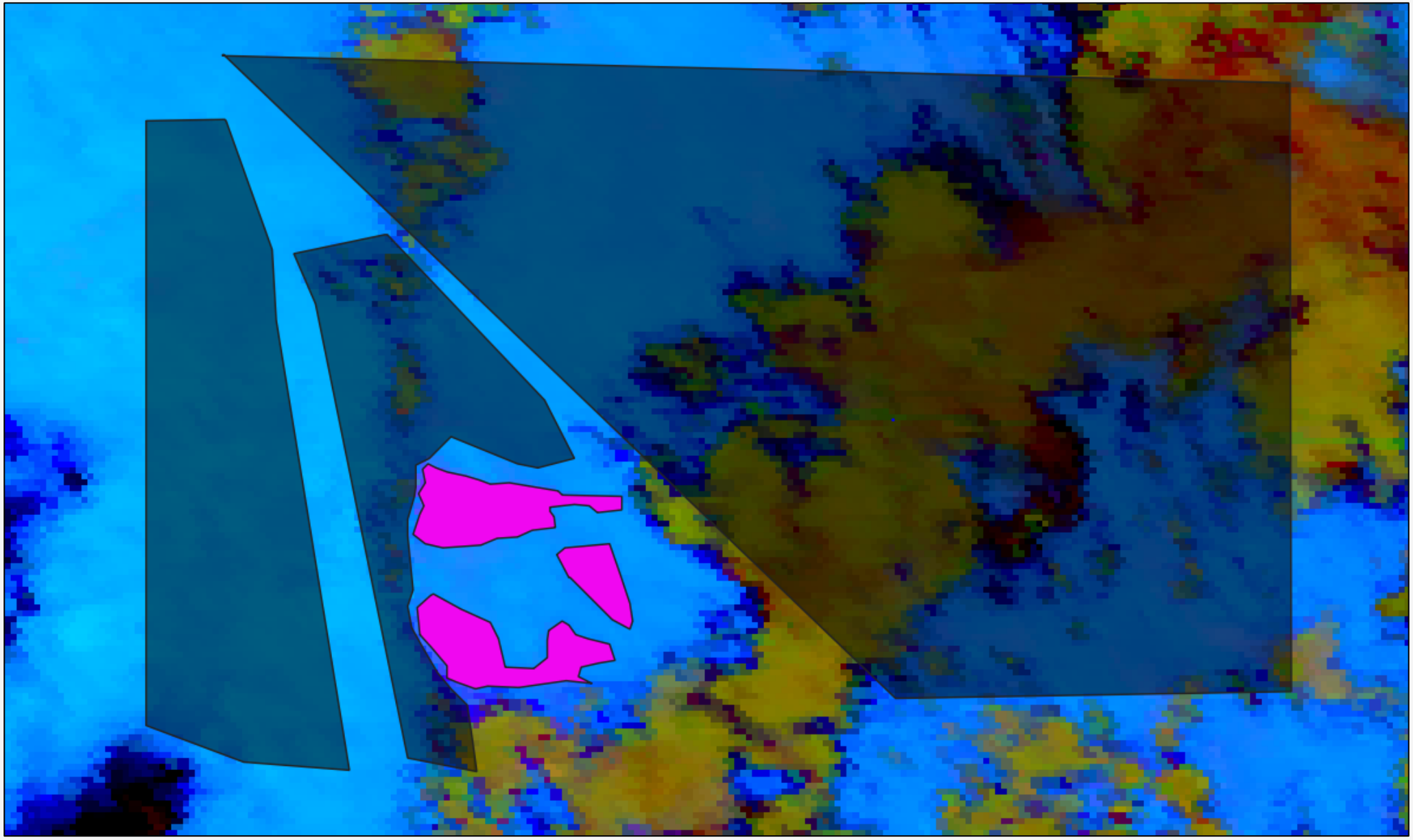


Adding Thunderstorm Outflow to Training

Date: 07/05/2018
Location: Southern Arizona
Description: Isolated Thunderstorms developed in the afternoon hours and generated gusty outflows that exceeded 40 mph.

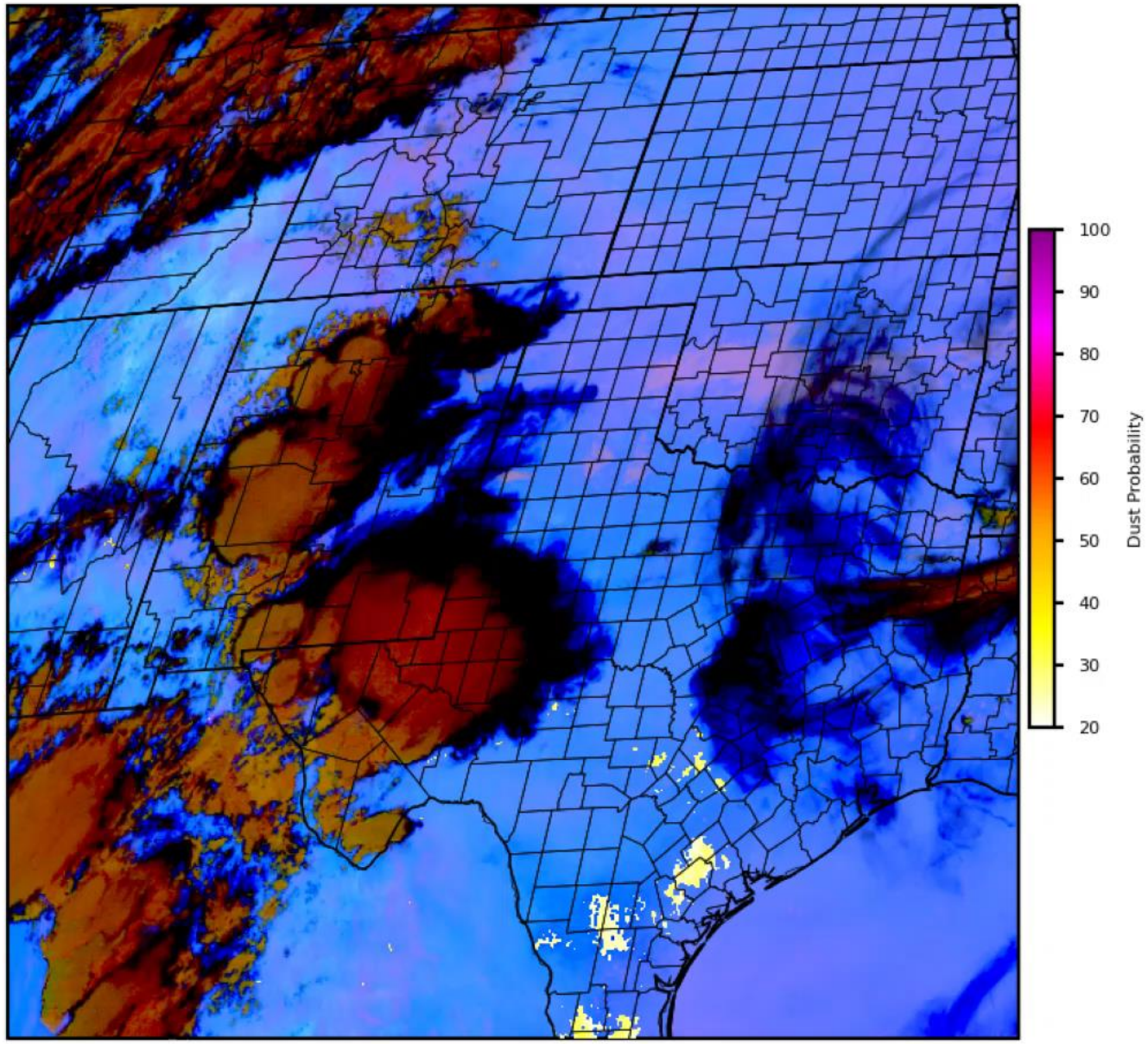


Best Performer Version 3 Training



V3

GOES-16 ABI Dust RGB with Dust Probabilities 2022-06-08 23:56 UTC



Works Cited

Berndt, E. B., Elmer, N. J., Junod, R. A., Fuell, K. K., Harkema, S. S., Burke, A. R., & Feemster, C. M. (2021). A machine learning approach to objective identification of dust in satellite imagery. *Earth and Space Science*, *8*(6). https://doi.org/10.1029/2021ea001788

Chomette, O., Legrand, M., & Marticorena, B. (1999). Determination of the wind speed threshold for the emission of desert dust using satellite remote sensing in the thermal infrared. *Journal of Geophysical Research: Atmospheres*, *104*(D24), 31207–31215. https://doi.org/10.1029/1999jd900756

Kim, H., & Choi, M. (2015). Impact of soil moisture on dust outbreaks in East Asia: Using satellite and assimilation data. *Geophysical Research Letters*, *42*(8), 2789–2796. https://doi.org/10.1002/2015gl063325

Stout, J. E. (2015). Diurnal patterns of blowing dust on the Llano Estacado. *Journal of Arid Environments*, *122*, 85–92. https://doi.org/10.1016/j.jaridenv.2015.06.013

Ucar/comet. (2010, December 21). *Forecasting Dust Storms - Version 2*. meted.ucar.edu/mesoprim/dust/. Retrieved June 6, 2022, from https://www.meted.ucar.edu/mesoprim/dust/print.php

Q&A

Dust ML Paper

(Berndt et al. 2021)

SPoRT Viewer

Machine Learning: GOES East
DustTracker-AI

NASA Visualization Studio

Finding Dust at Night